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SNAP Primary Mirror Distortions Due to Radiative Heat Loss

Introduction

Optical testing of the primary mirror will most likely occur with the primary mirror exposed to an essentially room-temperature thermal environment, whether in vacuum or surrounded by gas. But on orbit, the front face of the mirror will view cold portions of the observatory along with even colder deep space. The difference in mirror shape between these two environments is a component of the change from the as-tested configuration to the in-service configuration.

Distortions due to radiative heat loss in orbit of a possible design for a SNAP primary mirror are predicted using finite element analysis (FEA). The mirror design analyzed is a 1990mm outside diameter, open-back Zerodur design, detailed in SNAP-TECH-06008. Effects of bipods and flexures are eliminated by using boundary conditions to represent ideal kinematic mounting. Optical surface distortions are predicted based on heat flows calculated from an observatory thermal model.

Information on the SNAP mission and science are available at the SNAP home page, http://snap.lbl.gov.

The Model

The finite element model is based on the open-back Zerodur design detailed in the drawing SNAP-TECH-06008. The finite element model is illustrated in Figures 1 and 2. It is comprised mainly of plate elements, except in the mounting region, which contains brick elements. The total mass of the mirror is 208kg.

Figure 1 shows a side view of the model. This view illustrates the planar-tapered profile of the back of the mirror. From the central opening to a radius of 780mm, the back is flat. From 780mm radius outward, the back is tapered so the depth of the mirror at the outer diameter is approximately 130mm. The mirror depth is approximately 200mm at its deepest, at the corner between the flat and tapered zones.
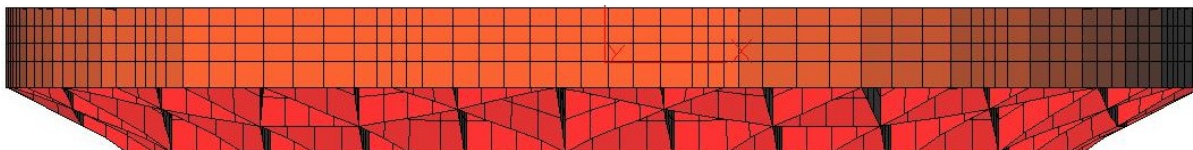

Figure 1-Side view of primary mirror model

Figure 2 shows the back side of the model. The spherical front face sheet in green is 8mm thick. The outer periphery in brown is 8mm thick. The ribs in red are 6mm thick, in a triangular isogrid pattern with each leg of each triangle 195mm long. The reinforced

mounting areas in blue are brick elements that extend from the front face to a plane recessed 150mm from the planar back of the mirror, within six of the triangular cells near two-thirds of the mirror outside diameter.

The mirror is supported at three points shown as red donuts, spaced 120 degrees apart. The support points are represented by boundary conditions, each of which allows freedom of rotation in all directions and allows freedom of translation only along lines radial to the mirror as shown by the double-headed arrows.
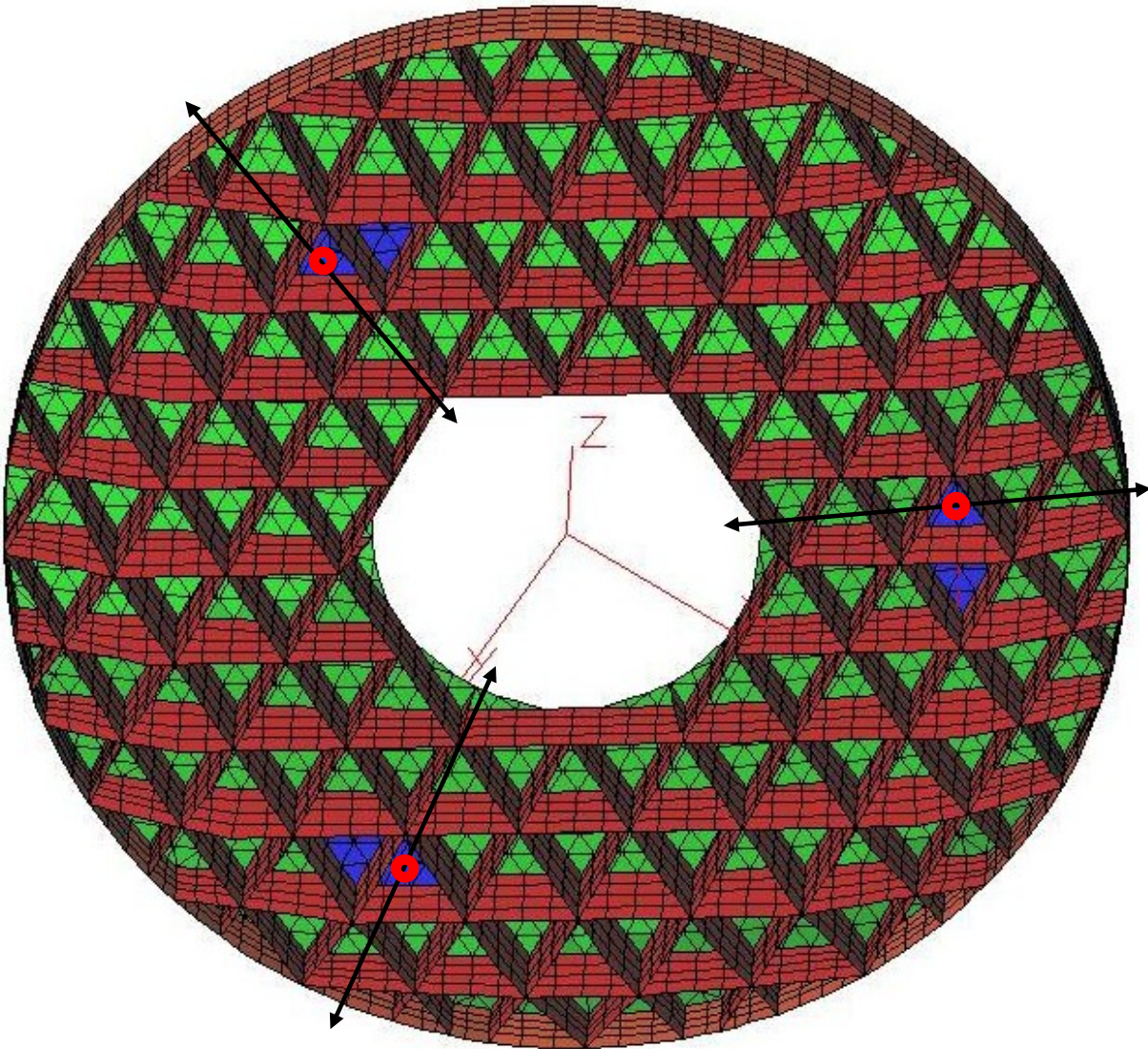

Figure 2-Back side of primary mirror model

Thermal profile

The heat flow through the mirror in orbit is calculated from a complete observatory thermal model. Essentially, the back and sides of the mirror couple radiatively with actively-heated telescope structure at room temperature. The front face of the mirror radiates out the baffle aperture to deep space, and it radiates to the relatively cold inner and outer baffles. The heat flow through the mirror is predicted to be 17 watts.

Because the back surface of the mirror's face sheet, the mirror ribs, and the telescope structure all view each other and only each other, they will couple closely. The ribs and back of the face sheet will be essentially isothermal, with heat flowing conductively from the back of the face sheet to the optical surface through the thickness of the face sheet.

For 17 watts to conduct through an area of 2.77 square meters and a length of 0.008 meters of Zerodur near room temperature ($k = 1.46$ W/m-K), the back-to-front temperature difference is -0.034K.

Modeling

The mirror is modeled in zero gravity on kinematic supports. The entire model aside from the front face is modeled with zero temperature change from the stress-free condition. The front face has imposed a mean temperature difference of -0.017K from the stress-free condition, along with a 0.034K temperature drop from the back of the face to the front of the face.

The coefficient of thermal expansion for the entire mirror is assumed to have a uniform value of 30e-9/K.

The axial distortions of the front face subject to the described environment are illustrated in Figure 3. The distortions amount to 1.2 nm peak-to-valley, clearly dominated by a defocus component. These distortions will not appreciably affect the validity of testing done at room temperature to predict performance on orbit.
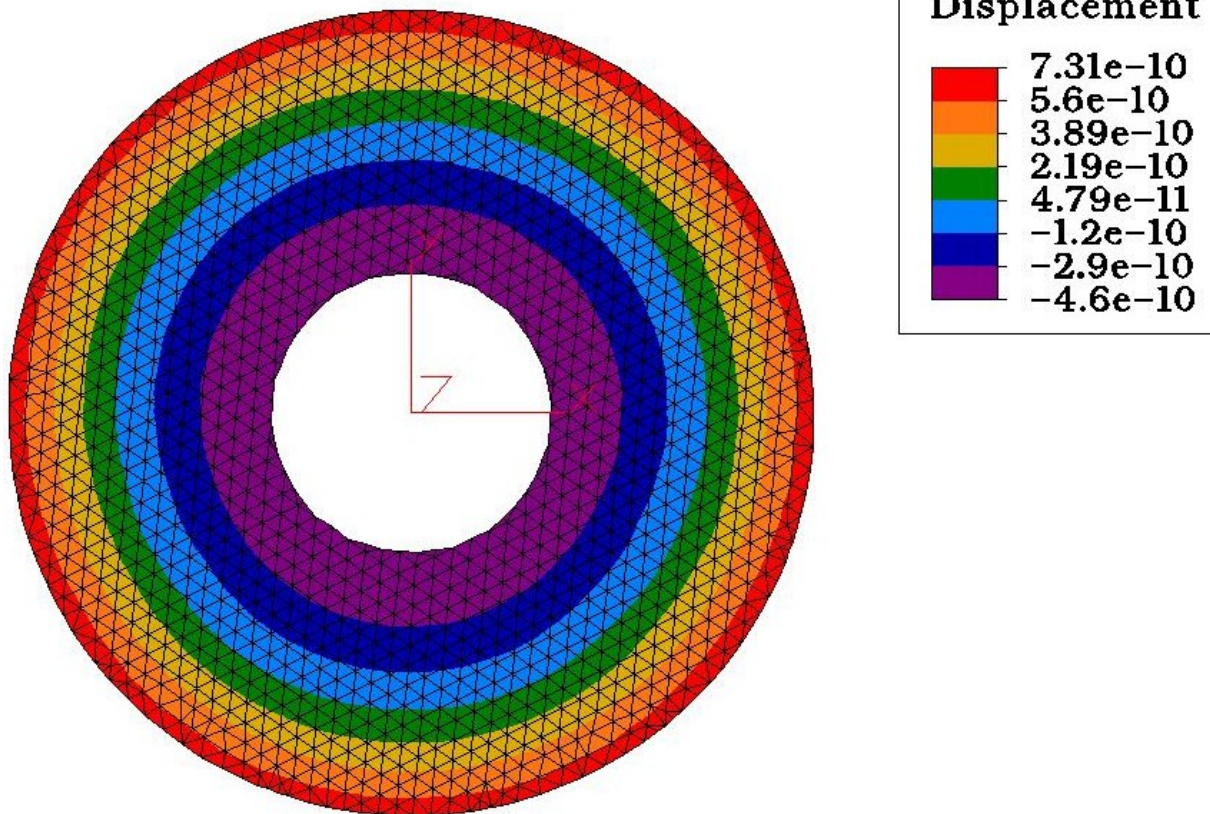

Figure 3-Axial surface distortions, in meters, 17 W conducting through front face sheet